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ABSTRACT

Four classroom activities are included in this 8-10 period unit suitable for high school chemistry and physics classes. The first activity is a reading (12th-grade readability level determined by the Fry procedure) which explains electricity conversion, transportation, and efficiency ratings. The second and third activities are electrical energy experiments: determining the efficiency of a light bulb and the relationship between heat and electricity. The last activity consists of problem sheets in which students analyze data and convert it into different forms of measurement while reviewing material previously discussed in the unit. Rationale, objectives, and instructional strategies are provided for each activity. A list of process skills fostered, advanced teacher preparation, goals, objectives, planning guide, and evaluation suggestions are provided in an introduction. (Author/JN)

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ELECTRICAL POWER GENERATION

Edited and Revised by

Hugh McDermott
Larry Scharmann

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A Basic Teaching Unit on Energy

SE039414

ELECTRICAL POWER GENERATION

Original Writer

Doug Wilson

Recommended Subjects: Senior High Physics and/or Chemistry

TO THE INSTRUCTOR . . . .

Physical Laws of Electral Power Generation is a self-inclusive unit with all necessary materials contained within. Its impact on students can be enhanced through the use of an electric utility representative as a resource speaker and/or an appropriate field trip. Teachers unfamiliar with all of the energy mass, weight and temperature units involved in the calculations will need to seek assistance from a physics text or visit with someone in the community having such familiarity.

Students will be given the opportunity to collect data and analyze results of experiments. The instructor will need to provide some basic procedures for calculations and assistance to individual students.

Since material sources continue to change periodically, the source, Energy Info - A Directory of Publications and Audio-Visual Materials From the Nebraska Energy Office, contains a list of general topics available from the Nebraska Energy Office. You are encouraged to use the ordering page attached to this unit to order this booklet as well as other energy related materials.

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ACKNOWLEDGEMENTS

The original "Basic Teaching Units on Energy" consisted of a package of 30 instructional packets contained within three volumes. The original fourteen units were written at the University of Nebraska-Lincoln, under the auspices of the Nebraska Energy Office, by Nebraska teachers participating in a three-week Faculty Development Institute sponsored by the U.S. Department of Energy (summer, 1978). The units were edited by the following individuals:

-Dr. Donald McCurdy, Professor of Science Education, University of Nebraska-Lincoln;
-Mr. Gary A. Lay, Education Coordinator, Nebraska Energy Office; and
-Dr. Robert Reeder, Science Department Chairman, East High School, Lincoln, Nebraska.

An additional eight units were written by independent authors in the summer of 1979 and the final eight units were developed as a result of a second federal grant (summer, 1980).

The present format has been achieved as a result of an evaluation conducted by the Nebraska Energy Office, February, 1981. Rather than continue to offer all 30 units as a single package, the Nebraska Energy Office determined to revise, edit, and typeset the 10-12 highest quality units and continue to offer the other units in their present format.

The editors of these revised "Basic Teaching Units" wish to thank the individual writers, original editors, and clerical staff for their contributions in creating the "Basic Teaching Units".

TABLE OF CONTENTS

PREFACE/INTRODUCTION 2

ABSTRACT/EVALUATION SUGGESTIONS 5

ACTIVITIES

#1 "PHYSICAL LAWS" 9

#2 "RELATIONSHIP BETWEEN HEAT AND ELECTRICITY" 22

#3 "DETERMINING THE EFFICIENCY OF A LIGHT BULB" 26

#4 "ADDITIONAL PROBLEMS" 30

SUPPLEMENTAL MATERIALS GUIDE 38

ENERGY INFORMATION REQUEST FORM 39

Abstract

Electricity is what can be called a secondary energy source--it is produced through the use of other sources of energy (primary sources). These primary sources are typically coal, petroleum, natural gas, falling water (hydroelectric) and uranium. Recent estimates show that these primary sources are providing the following contributions to the U.S. electrical generating capacity: coal = 54%, petroleum = 9%, gas = 12%, water = 14%, and nuclear = 11%.

Because heat is involved in the transformation of energy from most of these primary sources, one must look at the physical processes of energy conversion to develop an understanding of the limitations imposed upon these means of electrical generation.

This unit contains four classroom activities. "Physical Laws" explains electricity conversion, transportation and efficiency ratings. There are two electrical energy experiments: determining the efficiency of a light bulb and the relationship between heat and electricity. The last activity consists of additional problems which may require additional instructional assistance.

Recommended Level
Grades 9-12

Academic Areas
Physics and Chemistry

Readability Rating (Fry)

The readability rating level given for the reading below is based on the number of syllables per hundred words and number of sentences per passage. This reading level estimation will allow teachers the opportunity to perform some prereading exercises on vocabulary and concept development.

"Physical Laws" - 12th year

Time Required

Eight to ten class periods

Process Skills

-calculating
-data analyzing
-data gathering
-discussing
-experimenting
-observing
-problem solving
-reading

Advanced Teacher Preparation

Obtain: Energy films which may be applicable to a particular activity or unit.

Read: Energy Info - A Directory of Publications and Audio Visual Materials from the Nebraska Energy Office

Goals

1. Students will become familiar with the law of thermodynamics involved in the generation of electrical energy.

2. Students will gain a sense of the magnitude of the electrical generation process.

3. Students will develop competence in the use of numerical data for expressing energy unity and their relation to heat and electrical energy production and use.

Student Objectives:

1. Students will be able to explain the meaning of the First and Second Laws to Thermodynamics and give illustrations of their application.

2. Students will calculate the heat absorbed by a given quantity of water when supplied with ample temperature data.

3. Students will be able to calculate the temperature change of a given quantity of water when given the energy input.

4. Students will be able to determine the efficiency of a system given either thermal or mechanical energy inputs and outputs.

5. Students will convert electrical units to heat units and vice versa.

6. Students will determine kilowatt-hours of energy from electrical power and time data.

7. Students will convert watts to kilowatts and megawatts and vice versa.

Planning Guide

Day 1

Introduce the topic of electrical power generation

Day 2

Activity #1, "Physical Laws"

Day 3

Activity #2, "Relationship Between Heat and Electricity"

Day 4

Activity #3, "Determining the Efficiency of a Light Bulb"

Days 5

Activity #4, "Additional Problems"

Days 6-8

Additional time may be used to focus on any of the above activities.

Evaluation Suggestions

This unit allows teachers to develop their own instruments for evaluation. Many of the activities do have student worksheets which will give some indication of student success.

Physical Laws

Rationale: Physical laws relate to the problem of electrical efficiency. Two laws of thermodynamics explain the changes in energy form and the destruction of its usability.

Objectives: Students will be able to read "Physical Laws."
Students will be able to examine and interpret diagrams.
Students will be able to calculate the efficiency of a power plant, given some information.

Implementation: Hand out the reading "Physical Laws." As this is read, it may be necessary to give additional examples explaining the two laws of thermodynamics. Have students use the information on the student worksheet to solve the problem.

Debriefing: It may be necessary to go over the student worksheet with the class.

Name _____

Date _____

Physical Laws

energy conservation

Electricity is a very familiar and convenient source of energy. Energy present in a fossil or nuclear fuel is converted to energy in a form which is then transported by means of wires and readily distributed to residential, commercial and industrial customers.

energy transportation

Electricity is a useful carrier of energy since it is easily transported with little loss, methods have developed during the past 80 years for the safe handling of electricity, and the techniques of converting fossil and nuclear fuels to electric power are well developed, reasonably economical, and relatively safe.

consumer breakdown

In 1976 an estimated two trillion kilowatt-hours of electrical energy were generated in the U.S. with coal contributing 47 percent, oil 17 percent, natural gas 13 percent, hydroelectric 12 percent, and nuclear 11 percent. This electricity was used by the consuming sector as follows: residential 32 percent, commercial 23 percent, industrial 41 percent, and others 4 percent.

transformation costs

While electricity is relied upon as a major source of energy in the U.S., the generation of this electricity is a very expensive process from the standpoint of the conversion of fuel from one energy source to another. Another way of expressing this expense is to examine the efficiency with which this transformation is achieved.

defining efficiency

We typically define efficiency as the ratio of work taken from a system to the work put into that system. That system may be an automobile in which the work taken from the system is the work potential contained in the chemical energy of the gasoline. If the system is an electrical generating plant, the work taken from the system is all of the electrical energy made available to the consumers and the work input consists of the chemical or nuclear energy possessed by the fuel used in powering the electrical generator

work input: chemical or nuclear energy

energy loss through inefficiency

Automobiles and power plants are not alone in suffering from efficiency losses. While autos and power plants are typically about 25 percent and 35 percent efficient, respectively, other energy consuming sectors of the U.S. suffer similar inefficiencies as indicated by the table. As can be seen, America loses about two-thirds of the energy it consumes. Part of the reason for this loss is because there are absolute physical limits to efficiency.

1/3 of useful energy emerges

A more detailed account of the energy flow within the U.S. consuming sector can be seen in the following diagram. If we examine the efficiency of electrical generation, we find that only 5.3 Q (quads) of useful energy emerge from the 15.1 Q of energy placed into the electrical generation process.

The efficiency of such a process would be calculated as follows:

$$\text{efficiency} = \frac{\text{energy (work) output}}{\text{energy (work) input}} = \frac{5.3\ Q}{15.1\ Q} = 0.35 = 35\%$$

update data

The total energy utilized in the U.S. during 1980 is shown to be 78 Q. If only the four major sectors of energy use are considered, 60.3 Q of a total of 78 Q (60.3 + 17.7) was converted to useful work. The efficiency of use by these four sectors calculates to be 77.3%. More recent data indicate that the efficiency of these four sectors is lessening, partially due to increased dependence upon low-efficiency electrical generation, airplane and automobile transportation.

We Must Follow the Rules

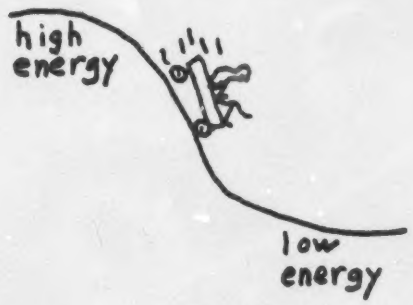
some basic physics

The electrical generating plant is an excellent illustration of how some physical laws relate to the problem of efficiency. To understand what this means in the grand scheme of things, we need to examine some basic physics. The First Law of Thermodynamics tells us that no matter or energy can be created or destroyed, just changed in form.

Coal becomes electricity and heat, iron ore becomes an automobile. But then the Second Law of Thermodynamics says, yes, something is destroyed--not the energy or matter itself, but the usability of it.

energy change

We might consider the sketch as an illustration of a system in which energy is undergoing a change. When the wagon is at the top of the hill, it has a high energy relative to the bottom of the hill.



potential energy

As it rolls down the hill, its energy of position (potential energy) is converted into energy of motion (kinetic energy). It finally reaches the bottom of the hill and gradually rolls to a stop because of various kinds of friction. We might say that when it reaches the bottom of the hill it has lost all of its potential energy. But has it? Not really. If the bottom of the hill had been lower, it

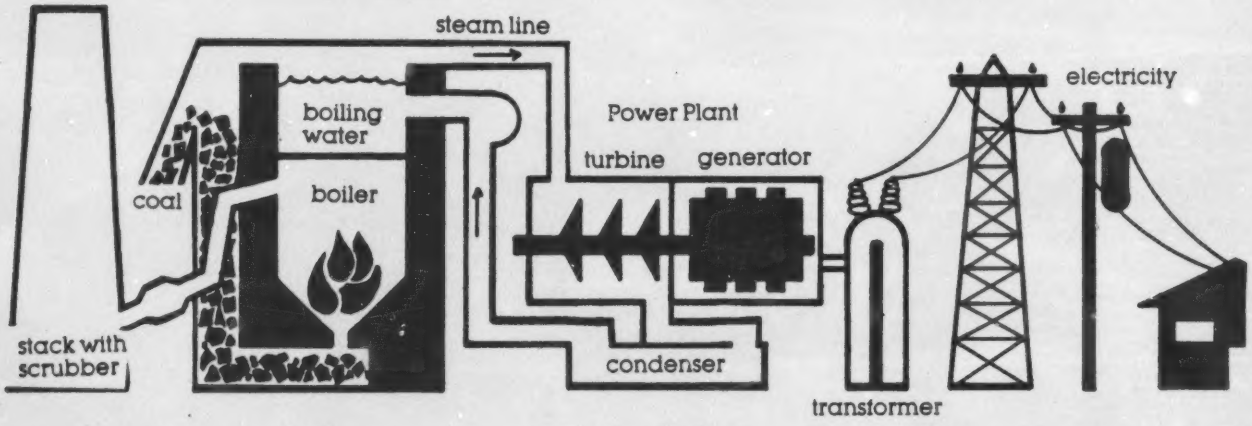
steam's working effort

could have lost more energy. But, given this hill, there is only a certain amount of energy that the wagon can lose. friction effect

If we want to return to the top of the hill, what must we do? We must put some work (energy) into the system. But, can we get by with only the amount of energy we lost in rolling down the hill? Not quite. Friction requires that we add a bit more energy than we appear to lose. In fact, we lose energy due to the work done in overcoming friction in both climbing the hill and in rolling down it. That work done against friction is just simply lost. It has become the unusable energy mentioned in the Second Law of Thermodynamics.

Examine the diagram of the electric generating plant. Water in the boiler is heated

FOSSIL FUEL (COAL) POWER PLANT



to a very high temperature until it becomes high pressure steam. This steam "falls" through a turbine--doing work on the turbine by causing it to turn. The steam reaches the bottom of its "energy hill" when it leaves the turbine and becomes water again in the condenser. It must now be returned to the top of the energy hill by being pumped into the boiler and reheated.

pressured steam and heat loss

Getting Steamed Up

The water in the boiler is heated to a very high temperature (600°-1200°F) by means of a fossil or nuclear fuel. Like the pressure cooker used in many homes, a rise in pressure (1,000 to 2,000 lb./in^2) also occurs. Because heat only flows effectively between areas of vastly different temperature, the temperature of the burning fuel is many hundreds of degrees hotter than the temperature of the steam (typical combustion temperatures will be around 2800°F). Heat generated by combustion which is not absorbed by the steam, passed from the combustion chamber through a tall smoke stack. This loss is typically about 10 to 12 percent of the heat content of the hundreds of tons of

fuel burned per hour. If nuclear fuel is used, essentially no heat is lost at this step.

how the turbine uses the steam

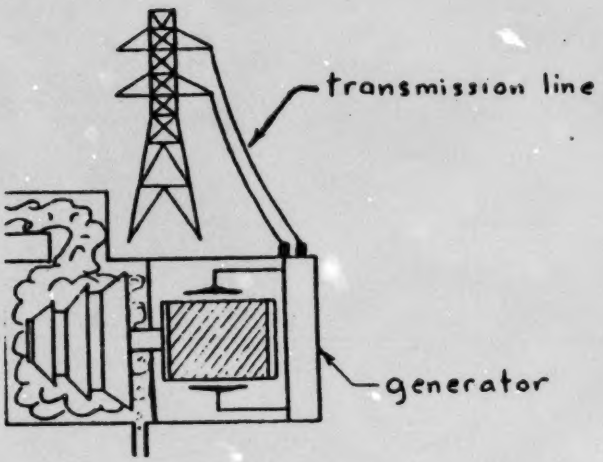
Getting Cooled Down

The super heated steam from the boiler is transported from the boiler to a turbine by means of highly-insulated pipes. It arrives at the turbine (a device consisting of many sets of blades mounted on a common shaft) and begins its journey through a maze of blades. Because of the steam's high temperature and pressure, it begins the journey by pushing against blades of fairly small size. As it loses temperature and pressure (energy loss from doing work), the blades it encounters become progressively larger in size so that work can still be effectively extracted from it. When the steam reaches the last set of blades, it is still hot and under some pressure. But its effectiveness as a working fluid has diminished to the point where it is not practical to attempt to remove any further work from it.

It's Electrifying

The generator turned by the turbine is a very complex machine weighing many, many tons. A very dense magnetic field is caused to intercept several miles of wire. This action of wires cutting across a magnetic field produces an electrical force, resulting in the current we use in our homes. Although generators are very efficient, there is some energy loss (typically about 1%) due to heat produced in this device.

The current from the generator is sent to a transformer where its voltage is multiplied many times (with an added loss of approximately 1%). To carry this resulting electrical energy to the consumer, many miles of wire are used and several more transformers. This is called the transmission process. This process may cause an additional 5 to 10% loss in energy, depending upon the distance which the electrical energy must be carried.



What's the Return?

When we look at the total electrical generating and distributing process, it is obvious that the major portion of the chemical or nuclear energy available in a fuel is not available to the consumer as electrical energy. It is not unusual to have only 30 percent of that initial amount delivered as useful energy. But, those are the rules and we must live by them. We cannot break the rules--we can only search for ways to play the power game more efficiently by minimizing heat losses where possible and making the best use of the small fraction of energy which is finally provided to us.

Electrical Power Generation
Your Turn
Student Worksheet, Page 1

Name _____

Date _____

Directions: You can now try your hand at determining how efficient one power plant is by using the information provided. In your calculations, try to determine how much hotter the cooling water might become if all but 15 percent of the waste heat is absorbed by this water.

Generating capacity	225,000 kilowatts
Cooling water	120,000 gallons per unit
Coal consumption	110 tons per hour
Coal heat content	12,500 Btu per pound

1 kilowatt hour = 3,415 Btu

1 gallon of water = 8.3 lb.

1 ton = 2,000 lb.

1 Btu is the heat required to change the temperature of 1 pound of water 1 Fahrenheit degree.

Relationship Between Heat and Electricity

Concept

Determining the quantity of heat added to water by an electrical heater.

Question

What is the quantity of heat supplied by the electrical heater for both procedures used in this experiment?

Objectives

Students will be able to observe and explore the electricity-heat relationship using an electric heating coil to warm water.
Students will be able to calculate the quantity of heat added to the water.
Students will be able to calculate the quantity of heat supplied by the electrical heater.
Students will be able to convert temperature readings to Fahrenheit units, given an equation.

Process Skills

calculating, demonstrating, measuring, observing, writing.

Time

Twenty (20) to thirty (30) minutes.

Background

Electricity as a form of energy for heating has become very common-place in the American home. The modern kitchen, in particular, has numerous appliances whose sole purpose is that of producing heat.

In this experiment you will explore the electricity-heat relationship by using a simple electric heating coil to warm water. Through the use of data collected during the heating process, the heating ability of electrical energy can be more fully understood.

Materials

8 to 14 ounce styrofoam cup
thermometer
100 ml graduated cylinder
one-cup electric heater (available in variety stores)

Procedure/Sequence

A. Place a 150 to 200 ml carefully measured volume of water into the cup and determine its temperature to the nearest 1/10 degree.

Place the electric heater into the water so that the coil is submerged as completely as possible. Do not submerge the plastic top. Plug in the heater for one minute and then unplug it. Gently stir the water with the unplugged heater for a few seconds and determine the temperature of the warmed water to the nearest 1/10 degree.

Remove the heater from the water and examine it for electrical information to determine its watt rating. For example, 225 W will mean 225 watts.

B. Repeat procedure A allowing the heater to operate for two minutes.

Electrical Power Generation
Relationship Between Heat & Electricity
Student Worksheet, Page 1

Name _____

Date _____

Directions: Using the following information, solve these problems.

Scientists and engineers use slightly different units when working with heat and electricity. To familiarize you with both systems of units, you will first use those units used by scientists and then those used most frequently by engineers.

1. For both procedures A and B, determine the quantity of heat added to the water by using the following relationship:

$$Q = MC \quad T$$

Q = heat in calories
m = mass of water in grams (1 ml=1g)
c = heat constant for water (1 cal/g C°)
T = temperature change of water (C°)

Procedure A _____ quantity of heat added to the water

Procedure B _____ quantity of heat added to the water

2. Using the relationship, 1W = 14.3 cal/minute, calculate the quantity of heat supplied by the electrical heater for both Procedures (A and B).

3. Ideally, the heat values determined in step one should be equal to the heat values found in step two. If they are not equal, examine their differences and suggest reasons for this variation.

_____

_____

_____

_____

Name _____

Date _____

4. Engineers use the same mathematical relationships as scientists for determining the heat gain of a substance, but the units are different. One of the first differences is in expressing the weight of the water. Determine the weight of water in the cup for each trial by using the following conversion:

453.6 g = 1.0lb

Procedure A _____

Procedure B _____

Next, convert each of the temperature readings to Fahrenheit units by use of the following equation:

$$F = 1.8C + 32$$

_____°Fahrenheit (A)

_____°Fahrenheit (B)

We can now use the statement:

$Q = Mc \quad T$

Q = heat in Btu's
m = weight of water in pounds
c = heat constant for water (1 Btu/lb F°)
T = temperature change in F°

5. While engineers use the watt as a unit of electrical power, they find it more useful in their work to determine the kilowatt-hours of energy and then convert this value (kWh) into Btu's. For example, 225 W for one minute would be
0.225 kW x 1/60 hr. = 0.00375 kWh

Electrical Power Generation
Activity #3

Determining the Efficiency of a Light Bulb

Concept

To provide a measure of the quantities of heat and light energies transformed from electrical energy.

Question

How can the quantities of heat and light energies transformed from electrical energy be measured?

Objectives

Students will be able to determine water temperatures.
Students will be able to convert kilowatts to Btu's.
Students will be able to calculate the quantity of heat delivered by the heater in activity #2.

Process Skills

calculating, demonstrating, measuring, observing, writing

Time

Twenty (20) to thirty (30) minutes.

Background

The ordinary light bulb is a very common means of converting electrical energy into light energy. Because the light is produced from a white-hot tungsten filament within the bulb, some of the electrical energy is converted to heat. This experiment is designed to provide a measure of the quantities of heat and light energies transformed from electrical energy.

Caution: Be sure the light bulb is immersed in the water as shown before connecting to a power source.

Electrical Power Generation
Activity #3

Materials

ring stand
buret clamp
8 to 14 oz. styrofoam cup
40 to 100 W light bulb
100 ml graduated cylinder
extension cord
lamp socket (plug-in type)
black ink or Tempra paint
thermometer

Procedure Sequence

Note: The bulb must be small enough so that it does not touch the sides of the cup when its glass envelope is totally submerged. Leave about 1/4 inch between the surface of the water and the rim of the lamp socket.

A. Arrange the materials as shown in the diagram. Add water to the cup until it reaches a level just below the rim of the lamp socket. Place a thermometer into the cup and determine the water temperature accurate to the nearest 1/10 degree. Plug in the extension cord for one minute and then unplug it. Gently stir the water with the thermometer for a few seconds and read the new temperature accurate to the nearest degree. Remove the bubl from the cup and pour the water into a graduated cylinder to determine its volume and mass (1 ml = 1 g).

B. Repeat Part A for 2 minutes.

C. Repeat Part A using a mixture of ink (or black Tempra paint) and water which forms an opaque mixture.

D. Repeat Part A using a mixture of ink (or black Tempra paint) for 2 minutes.

Electrical Power Generation
Determining the Efficiency
of a Light Bulb
Student Worksheet, Page 1

Name _____

Date _____

Directions: Using the information from the experiment, answer the following problems.

1. Calculate the heat absorbed by the water for the various times in the experiment through the use of the following formula:

$$Q = Mc \quad T$$

Q = heat absorbed by the water in calories
m = mass of water in grams
c = heat constant for water (1 cal/g C°)
T = change in temperature of water in C°

_____ after one minute
_____ after two minutes

2. Determine the electrical energy consumed by the bulb using the following table:

bulb size (watts)	energy consumption (cal/minute)
25	358
40	573
60	860
75	1,074
100	1,432

_____

_____

_____

_____

Name _____

Date _____

3. Calculate the electrical energy not converted to heat (light energy) for each part as follows:

light energy = electrical energy - heat energy.

_____

_____

_____

_____

4. Calculate the lighting efficiency of the bulb for each part by using the following relationship:

$$\text{efficiency} = \frac{\text{light energy}}{\text{electrical energy consumed}}$$

_____

_____

_____

_____

5. What is the effect of placing the ink (or paint) in the water?

_____

_____

Data conversions for Conventional System (if desired)

1 W = 0.057 Btu/minute
453.6 g = 1 lb.
1 C° = 1 F°

Rationale: Analyzing data and converting it into different forms of measurement is necessary and useful in solving problems. Students are given an opportunity to practice what they have learned throughout the unit.

Objectives: Students will be able to calculate data. Students will be able to solve problems.

Implementation: Hand out "Additional Problems." It may be necessary to assist students in establishing equations. Students will then work through them.

Debriefing: Have students work in pairs to correct their work.

Electrical Power Generation
Additional Problems
Student Worksheet, Page 1

Name _____

Date _____

Directions: Can you do these problems? Attempt as many as you can.

1. Express each of the following in watts (W):

a. 2.1 kW _____
b. 45.8 kW _____
c. 1.5 MW _____
d. 1200 MW _____
e. 0.010 kW _____
f. 0.650 kW _____
g. 0.0002 MW _____
h. 0.055 MW _____

2. Express each of the following in kilowatts (kW):

a. 1,000 W _____
b. 60 W _____
c. 1,200 W _____
d. 4 W _____
e. 50,000 W _____
f. 8×10^5 W _____
g. 60×10^6 W _____
h. 1,000,000,000 W _____

3. Express each of the following in megawatts (MW):

a. 1,000,000 W _____
b. 1,000,000,000 W _____
c. 800,000 W _____
d. 800,000,000 W _____
e. 60,000 W _____
f. 46,000,000,000,000 W _____
g. 77×10^{15} W _____
h. 12×10^6 W _____

4. Express the following electrical usages in kilowatt hours (kWh):

a. 80C W used continuously for 15 hours _____

b. 1,500 W used 15 minutes daily for 30 days _____

c. 4 W used continuously for 30 days _____

d. 4.5 kW used 10 minutes per hour for 30 days _____

5. Using the relationship that 1 kWh = 3,415 Btu, make the following conversions:

a. 5 kWh = _____ Btu
b. 8,000 Btu = _____ kWh
c. 0.050 kWh = _____ Btu
d. 300 Btu = _____ kWh
e. 9400 kWh = _____ Btu
f. 100,000 Btu = _____ kWh

Name _____

Date _____

6. A common light bulb has an electrical power rating of 100 W.

   a. Express this rating in kilowatts (kW)

   _____

   b. If the bulb is operated 80 hours, how much energy will it consume in kilowatt-hours?

   _____

7. The electric heater used to warm the ticket booth at a football game has an electrical power rating of 1500 W.

   a. How many kilowatt-hours of energy will this heater consume during a 3 hour period?

   _____

   b. How much heat (in Btu's) will the heater produce during this 3 hour period?

   _____

8. Calculate the heat (in Btu's) required to warm the following quantities of water by the indicated amounts.

   a. 10 lb. of water from 50°F to 80°F.

   _____

   b. 45 lb. of water from 50°F to 120°F.

   _____

   c. 500 lb. of water from 55°F to 140°F.

   _____

   d. 62.4 lb. of water from 35°F to 180°F.

   _____

Name _____

Date _____

9. For each of the following quantities of heat added to the amount of water listed, calculate the temperature change which would occur to the water.

   a. 1,000 Btu added to 20 lb. of water.

   _____

   b. 6,000 Btu added to 400 lb. of water

   _____

   c. 5×10^4 Btu added to 350 lb. of water

   _____

   d. 4.5×10^6 Btu added to 2.4×10^5 lb. of water.

   _____

10. A 50 gallon tank of water is to have its temperature raised from 60°F to 130°F.

   a. How many Btu's of heat will be required to carry out this tank if each gallon of water weighs 8.3 lb?

   _____

   b. If 1 kWh of electrical energy produces 3,415 Btu, how many kWh will be needed to supply this quantity of heat?

   _____

11. The furnace of a house burns natural gas at a rate which provides 100,000 Btu/hr. Yet, only 80,000 Btu/hr. is removed from the furnace in the form of useful heat (the remaining 20,000 Btu/hr escaping up the chimney). What is the efficiency of the furnace?

   _____

Name _____

Date _____

12. A gasoline motor is 25% efficient. It burns 3 gallons of gasoline per hour.

    a. If the gasoline has a heat value of 140,000 Btu/gallon, how much heat is wasted by the motor per hour?

    _____

    b. If the motor operates a 95% efficient electrical generator, how many kilowatts of power will the generator produce?

    _____

13. When coal is burned, it typically yields heat of approximately 13,000 Btu/lb. How much heat would be produced from the burning of 1 ton of coal?

    _____

14. A small electrical power plant burns 110 tons of coal per hour?

    a. If the heat content of the coal is 13,000 Btu/lb., how many Btu's of heat will be produced per hour?

    _____

    b. If all of this heat could be converted into electrical energy, what would be the electrical generating capacity of the plant in kilowatts?

    _____

    c. The plant is found to have an operating efficiency of 27%. What is the actual generating capacity of the plant in kilowatts?

    _____

15. The power plant in the above problem uses water flowing at the rate of 120,000 gallons per minute to extract waste heat from the condenser of the turbine.

    a. How many gallons of water flow through the condenser per hour?

    _____

Name _____

Date _____

b. What weight of water flows through the condenser per hour?

_____

c. If 60% of the heat lost by the plant is lost in the turbine, what quantity of heat is carried away by the cooling water per hour?

_____

d. When the cooling water leaves the condenser, how many degrees higher in temperature has it become compared to when it entered the condenser?

_____

1. a. 2,100 W
   b. 45,800 W
   c. 1,500,000 W
   d. 1,200,000,000 W
   e. 10 W
   f. 650 W
   g. 200 W
   h. 55,000 W

2. a. 1 kW
   b. 0.06 kW
   c. 1.2 kW
   d. 0,004 kW
   e. 50 kW
   f. 8×10^2 kW
   g. 60×10^3 kW
   h. 1,000,000 kW

3. a. 1 MW
   b. 1,000 MW
   c. 0.8 MW
   d. 800 MW
   e. 0.06 MW
   f. 46,000 MW
   g. 77×10^9 MW
   h. 12 MW

4. a. E = 0.8 kW x 15 h = 12kWh
   b. E = 1.5 kW x 1/4 h/day x 30 days = 11.25 kWh
   c. E = 0.004 kW x 24 h/day x 30 days = 2.88 kWh
   d. E = 4.5 kW x 1/6 h/h x 24 h/day x 30 days = 540 kWh

5. a. Q = 5 kWh (3415 Btu/kWh) = 17,075 Btu
   b. E = 8000 Btu/3415 Btu/kWh = 2.34 kWh
   c. Q = 0.050 kWh (3415 Btu/kWh) = 171 Btu
   d. E = 300 Btu/3415 Btu/kWh = 0.088 kWh
   e. Q = 9400 kWh (3415 Btu/kWh) = 3.21×10^7 Btu
   f. E = 100,000 Btu/3415 Btu/kWh = 29.3 kWh

6. a. 0.1 kW
   b. E = 0.1 kW x 80 h = 8 kWh

7. a. E = 1.5 kW x 3 h = 4.5 kWh
   b. Q = 4.5 kWh x 3415 Btu/kWh = 15,370 Btu

8. a. Q = 10 lb. x 1 Btu/lb F° x 30 F° = 300 Btu
   b. Q = 45 lb. x 1 Btu/lb F° x 70 F° = 3150 Btu
   c. Q = 500 lb. x 1 Btu/lb F° x 85 F° = 42,500 Btu
   d. Q = 62.4 lb. x 1 Btu/lb F° x 145 F° = 9050 Btu

9. a. T = 1000 Btu/(1 Btu/lb F°) 20 lb = 50 F°
   b. T = 6000 Btu/(1 Btu/lb F°) 400 lb = 15 F°
   c. T = 5×10^4 Btu/(Btu/1 lb F°)(2.4×10^5 lb) = 18.8F°

10. a. weight = 50 gal. x 8.3 lb/gal = 415 lb.
    Q = 415 lb x 1 Btu/lb F° x 70F° = 29,050 Btu

    b. E = 29,050 Btu/(3415 Btu/kWh) = 8.5 kWh

11. Eff = 80,000 Btu/h/100,000 Btu/h = 0.80 = 80%

12. a. $Q = 3 \text{ gal/h} \times 140{,}000 \text{ Btu/gal} \times 0.75 = 315{,}000 \text{ Btu/h}$

    b. $E = 3 \text{ gal/h} \times 140{,}000 \text{ Btu/gal} \times 0.25 \times 0.95/3.45 \text{ Btu/kwh} = 29.2 \text{ kW}$

13. $Q = 1.3 \times 10^4 \text{ Btu/lb} \times 2000 \text{ lb/ton} = 2.6 \times 10^7 \text{ Btu/ton}$

14. a. $Q = 1.3 \times 10^4 \text{ Btu/lb} \times 2000 \text{ lb/ton} \times 1.10 \times 10^2 \text{ ton/h} = 2.86 \times 10^9 \text{ Btu/h}$

    b. $E = 2.86 \times 10^9 \text{ Btu/h}/(3415 \text{ Btu/kWh}) = 837{,}000 \text{ kW}$

    c. $E = 0.27 \times 837{,}000 \text{ kW} = 226{,}000 \text{ kW}$

15. a. $V = 1.2 \times 10^5 \text{ gal/min} \times 60 \text{ min/h} = 7.2 \times 10^6 \text{ gal/h}$

    b. $W = 7.2 \times 10^6 \text{ gal/h} \times 8.3 \text{ lb/gal} = 6.0 \times 10^7 \text{ lb/h}$

    c. $Q = 0.60 \times 2.86 \times 10^9 \text{ Btu/h} = 1.72 \times 10^9 \text{ Btu/h}$

    d. $T = 1.72 \times 10^9 \text{ Btu/h}/(1\text{Btu/lb F°})(6.0 \times 10^7 \text{ lb/h}) = 28.6\text{F°}$

SUPPLEMENT

Books

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Exploring Power Technology: Basic Fundamentals. John R. Walker, Goodheart-Wilcox Company, Il., 1976.

Fuel Cells: A New Kind of Power Plant, U.S. Department of Energy, Technical Information Center, Oak Ridge, TN., 1976.

Sources of Print and Nonprint Materials Crowley, Maureen, ed., Neal-Schuman. 1980.

Magazine

Electric Forum. General Electric Company.

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